CHAPTER 8

SETTLEMENT IN ELASTIC MEDIA

تنضغط التربة نتيجة تأثرها بالاحمال الواقعة على سطحها او بداخلها . وتعتمد قيمة الانضغاط على قيمة الحمل والظروف المحيطة . ومجموع الانضغاطات للنقاط الواقعة على خط رأسى من التربة تظهر فى صورة هبوط فى سطح الارض عند تلاقى هذا الخط الرأسى مع السطح . ويتناول هذا الباب هبوط سطح الارض نتيجة حمل واقع على سطحها , اما مُركّز او موزع بانتظام على المساحة ، باعتبار التربة جسم متجانس مرن نصف لانهائي يتبع قانون هوك .

This Chapter presents the displacement of soil surface due to different cases of loading. This settlement is the accumulation of the elastic displacement in the soil mass assuming that this mass is semi- infinite, elastic and isotropic.

8.1 Settlement due to concentrated load

For concentrated load (Q) acting on the surface of a semi- infinite, homogenous, linearly elastic media, the settlement is given by: (Fig. 8.1)

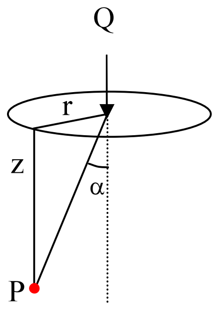


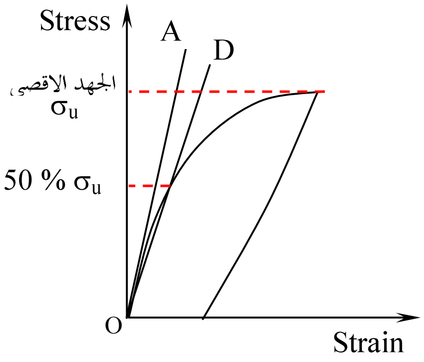
Fig. 8.1 Effect of concentrated load

$$\rho = \frac{Q}{2\pi r}\left[\frac{(1+\upsilon)}{E}\right]\left[2\left(1-\upsilon+\cos^2\alpha\right)\right]\sin\alpha \qquad \text{.. .. .. (8.1)}$$

The settlement at the surface is given by:

$$\rho = \frac{Q}{\pi r}\frac{\left(1-\upsilon^2\right)}{E} \qquad \text{.. .. .. (8.2)}$$

حساب الهبوط بتطبيق نظرية المرونة لايعنى ان التربة مرنة تماما. والواقع ان التربة لدنة ولها بعض المرونة. معنى ذلك انه عند التحميل يحدث انفعال فى التربة ، ومع ازالة الحمل تسترد التربة جزء فقط من الانفعال. يمكن تمثيل ذلك بالمنحنى المبين. وفى الشكل الخط (OA) مماس للمنحنى من نقطة الاصل وميلة يعرف بمعامل المرونة المماسى ($Tangent\ modulus - E_i$) ويمكن تطبيقه فى الحالات التى يكون فيها مستوى الجهد المعرضة له التربة منخفضا. اما فى حالات المستوى المتوسط للاجهادات فيفضل تطبيق المعامل القاطع ($Secant\ modulus - E_s$) وهو ميل الخط (OD).



يبين جدول (8.1) قيم نموذجية لمعامل مرونة التربة ، كما يبين جدول (8.2) قيم نموذجية لنسبة بواسون للتربة.

جدول (8.1) :

Soil	$E - kg/cm^2$
Soft clay	20 – 40
Firm clay	40 – 100
Stiff clay	100 – 200
Silt	20 – 200
Silty sand	50 – 200
Loose sand	100 – 250
Dense sand	500 – 1000
Loose sand and gravel	500 – 1400
Dense sand and gravel	800 – 2000

جـدول (8.2) :

Soil	ν
Saturated clay	0.4 – 0.5
Unsaturated clay	0.1 – 0.3
Sandy clay	0.2 – 0.3
Silt	0.3 – 0.35
Loose sand	0.25 – 0.3
Dense sand	0.15 – 0.25

8.2 Settlement due to flexible loaded area

For a rectangular area the settlement at its corner is given by:

$$\rho = q \cdot b \frac{\left(1-\upsilon^2\right)}{E} \cdot I_\rho \qquad \text{.. .. .. (8.3)}$$

where I_ρ is a dimensionless factor which depends on the ratio of the length (a) to width (b) of the area (a > b). Values of I_ρ are plotted in Fig. 8.2.

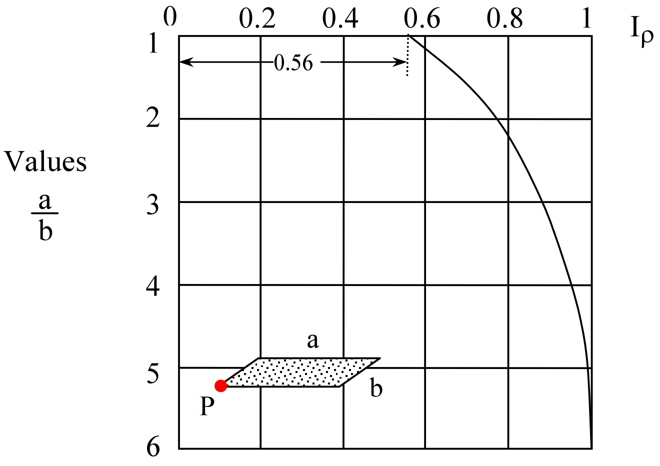


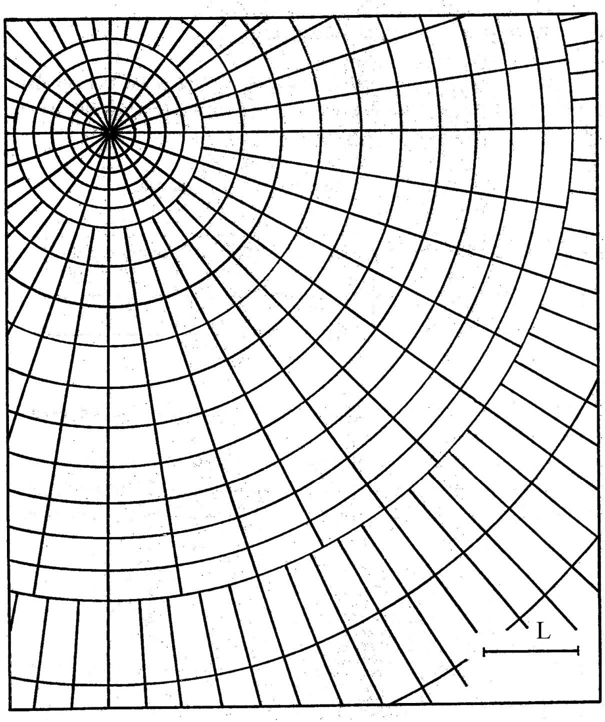
Fig. 8.2 Shape factors

8.3 Settlement due to circular or irregular shaped flexible loaded area

This method is given after Newmark, Fig. 8.3, as follows:

1. The plane of the area is drawn to any suitable scale on a tracing paper and the distance (L) on the chart is determined to this scale.
2. The tracing paper is placed over the chart and the point under which the settlement is required is placed over the centre of the chart.
3. The number of the influence areas enclosed by the outline of the loaded area is counted (N).
4. The influence factor (I_ρ) is calculated from : $I_\rho = 0.02\ N$
5. The surface settlement is calculated from the equation:

$$\rho = q \cdot L \frac{(1-\upsilon^2)}{E} \cdot I_p \qquad \text{.. .. .. (8.4)}$$



Influence value
0.02

Fig. 8.3 Newmark chart for elastic settlement

8.4 Settlement due to rigid loaded area

In case of rigid area the settlement will be equal. For circular, square and rectangular areas, Equ. (8.3) Will be applied (For circular area b = diameter). Table 8.3 gives the shape factors.

Table 8.3 Shape factor for rigid loaded area

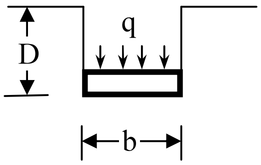
Shape	Circular	Square	Rectangle (a/b)				
			1.5	2	5	10	100
I_ρ	0.88	0.82	1.06	1.2	1.7	2.1	3.4

8.5 Settlement due to embedded rigid rectangular loaded area

In case of embedded rigid rectangular area (a x b) at depth (D) loaded by uniform load (q), Equ. (8.3) is applied with the shape factors given in Table 8.3 multiplied by a correction factor (C) as given in Table 8.4.

Table 8.4 Correction factors for use with the shape factors given in Table 8.3

D/B	Correction factor (C)			
	a/b = 1		a/b = 5	
	$\nu = 0.3$	$\nu = 0.5$	$\nu = 0.3$	$\nu = 0.5$
0.5	0.82	0.88	0.90	0.95
1	0.65	0.72	0.78	0.85
2	0.56	0.62	0.68	0.75
3	0.50	0.55	0.57	0.62



$$\rho = q \cdot b \cdot \left[\frac{\left(1 - \upsilon^2\right)}{E} \right] \cdot I_p \cdot C$$

8.6 Examples

(1) A concentrated load of 40 t acts on ground surface. Draw a cross section passing through the load showing the elastic line of settlement of the ground surface. Assume that the soil can be represented by a semi-infinite elastic media whose modulus of elasticity (E) is 800 kg/cm^2, and Poissson's ratio (ν) is 0.3.

Solution:

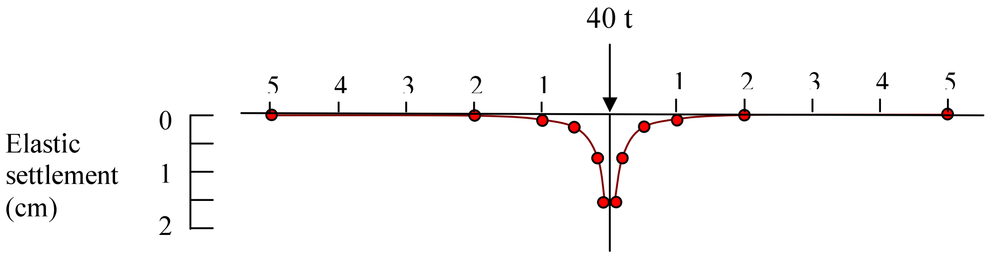
$$\rho = \frac{Q}{2\,r}\,\frac{(1-\nu^2)}{E}$$

$$= \frac{40000}{2\,r}\,\frac{(1-0.3^2)}{800}$$

$$= \frac{14.483}{r}$$

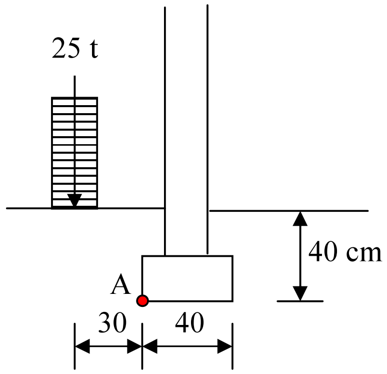
Taking different values of r, we get :

r - m	0.1	0.2	0.5	1	2	5
ρ - cm	1.448	0.724	0.290	0.145	0.070	0.029



(2) A compacting machine moves at a speed of 36 m/hour. The wheel near a wall carries a load of 25 t The wheel is assumed to exert a concentrated load on the ground. Draw the relation between the time and elastic settlement caused by the wheel load for any point (A) at the corner of the wall foundation. The soil is assumed to have elastic properties.

Solution:

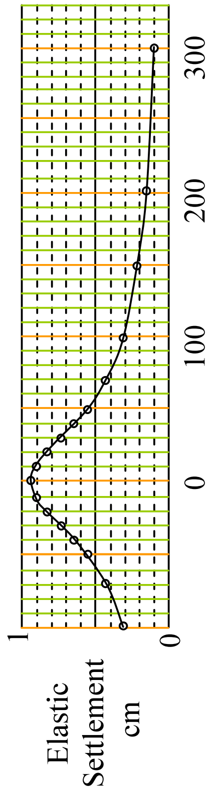


Assume time (t = 0) when the wheel comes across point (A). Then, at time t = 0, r = 30 cm. Since the speed is 36 m/h, then the wheel load moves known distances parallel to the wall, from which r for various times can be obtained. Knowing r and z = 40 cm, angle (α) can be obtained (α = tan-1 {r/z}). To obtain the elastic settlement (ρ) for each position, apply the equation:

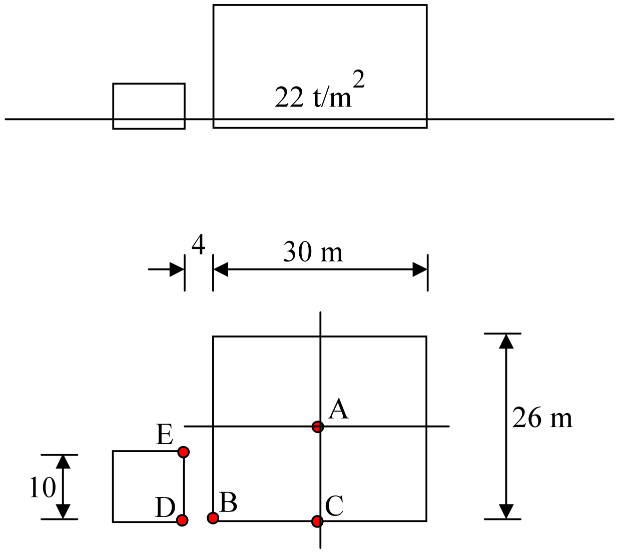
$$\rho = \frac{Q}{2\,\pi\, r}\cdot\frac{1+\nu}{E}\cdot[2\,(1-n)+\cos^2\alpha]\cdot\sin\alpha$$

The following results are obtained using a programmable calculator, then drawn as shown in figure.

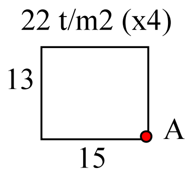
Time sec.	r cm	ρ cm
0	30.0	**0.940**
10	31.6	**0.910**
20	36.1	0.830
30	42.4	0.740
40	50.0	0.645
50	58.3	0.555
70	76.2	0.430
100	104.4	0.315
150	153.0	0.215
200	202.2	0.160
300	301.5	0.105

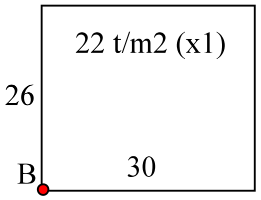


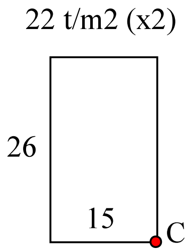
(3) A new building is constructed near an old building, as shown in figure. Calculate for both buildings the elastic settlement for points A, B, C, D and D. Assume that the foundation is flexible at ground surface. Dimensions and soil data are as shown in the figure.

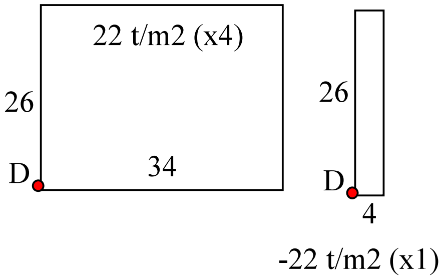


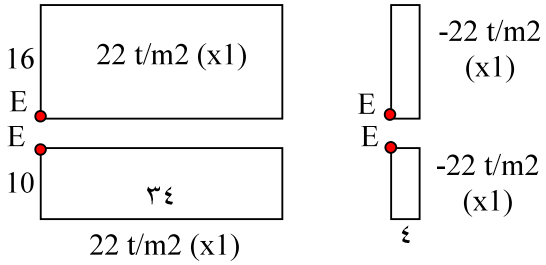
Solution:





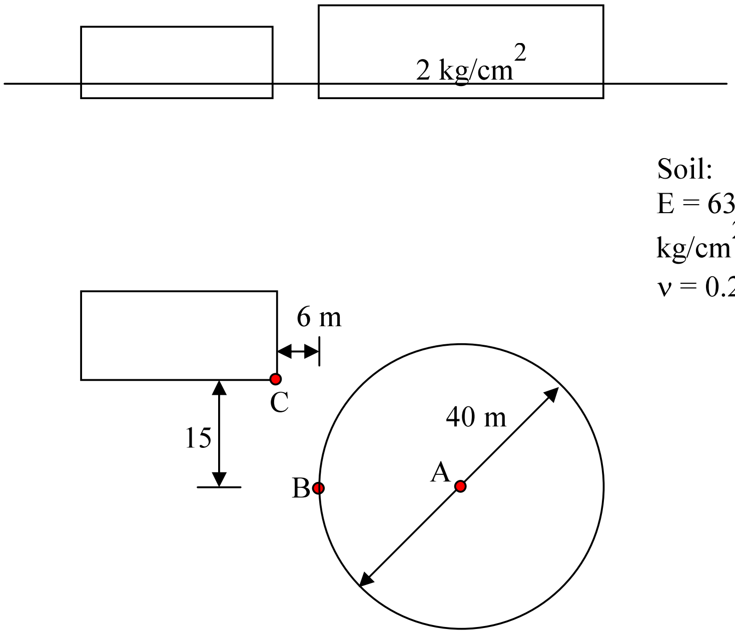






Point	q t/m^2	a m	b m	$\frac{a}{b}$	I_ρ	ρ cm	Num. Repet	$\Sigma \rho$ cm	ρ Total cm
A	22	15	13	1.15	0.601	5.22	4	20.88	20.88
B	22	30	26	1.15	0.601	10.44	1	10.44	10.44
C	22	26	15	1.73	0.722	7.23	2	14.46	14.46
D	22	34	26	1.31	0.638	11.07	1	11.07	
	22	26	4	6.5	1.135	-3.03	1	-3.03	
									8.04
E	22	34	16	2.13	0.784	8.38	1	8.38	
	22	34	10	3.4	0.930	6.21	1	6.21	
	22	16	4	4.0	0.981	-2.62	1	-.2.62	
	22	10	4	2.5	0.834	-2.23	1	-.2.23	
									9.74

(4) A new building is constructed near an old building, as shown in figure. Calculate for both buildings the elastic settlement for points A, B and C. Assume that the foundation is flexible at ground surface. Dimensions and soil data are as given in figure.



Soil:
$E = 630\ kg/cm^2$
$\nu = 0.27$

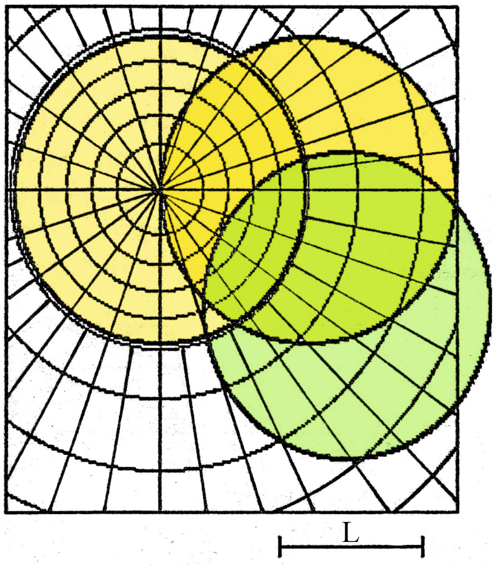
Solution:

Draw the plan to scale 2.4 cm = 20 m

$\therefore$ L = 20 m

Use the equ.:

$$\rho = q \cdot L \cdot \frac{1-\nu^2}{E} I\rho$$

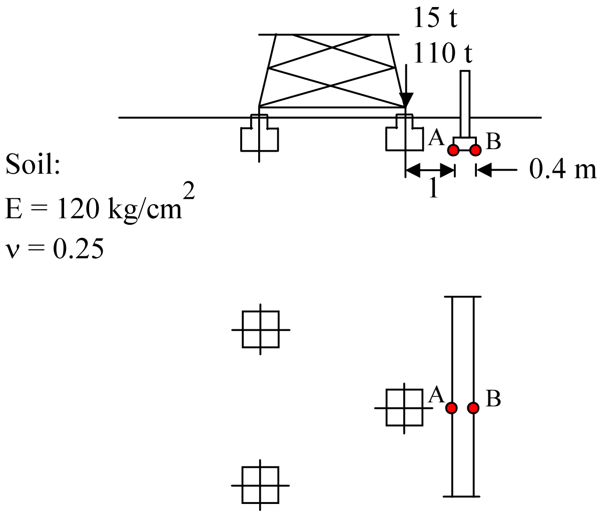


Influence value
0.02

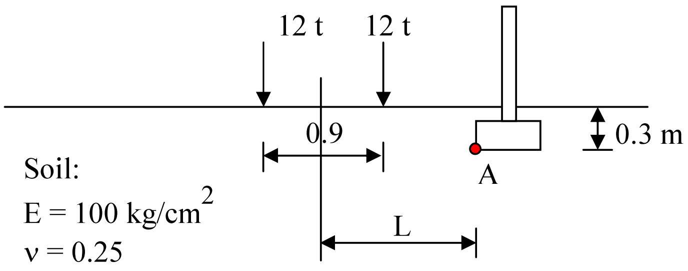
Point	N	Iρ	ρ cm
A	96	1.92	11.3
B	43	0.86	5.06
C	35	0.70	4.12

8.7 Problems

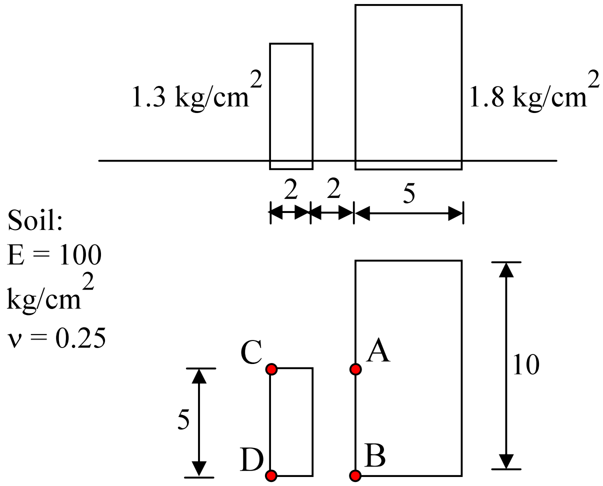
(1) A tower is built near a wall. The compression on each tower footing can vary between 15 and 110 t. Calculate the maximum and minimum differential settlements of points A and B of the wall foundation. Assume that the compression on tower footing acts as a concentrated load, and that both tower and wall footings are on ground surface. Dimensions and soil data are as shown in figure.



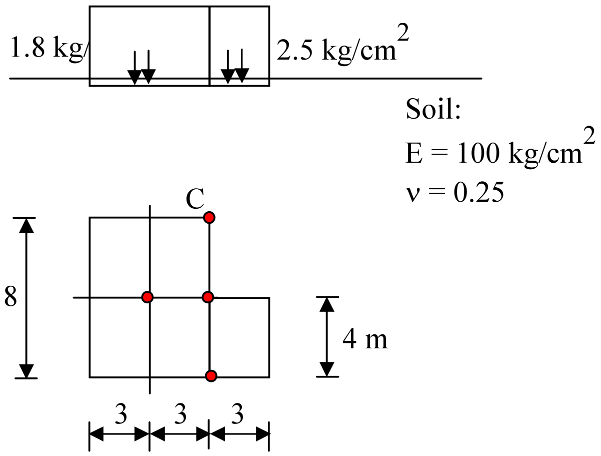
(2) Two concentrated loads each 12 t act on the ground surface. Find the minimum distance (L) such that the settlement of point (A) of a wail foundation does not exceed 2 mm. Dimensions and soil data are as shown in figure.



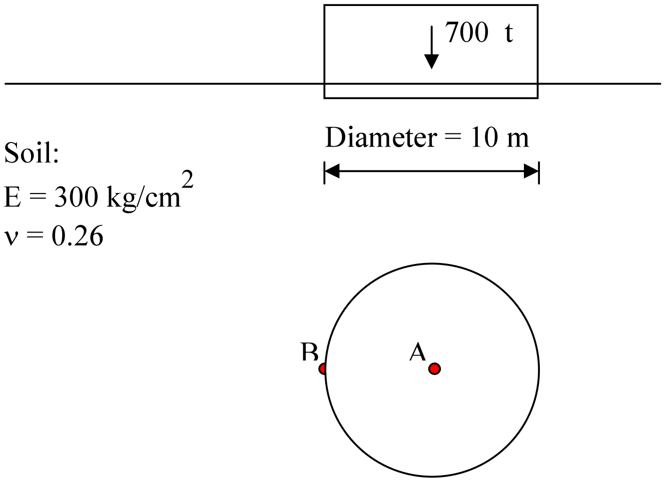
(3) The loads of two buildings are as shown in figure. Assuming that the foundations are flexible and that the loads act on ground surface, find the elastic settlement of points A, B, C and D. Dimensions and soil data are as shown in figure.



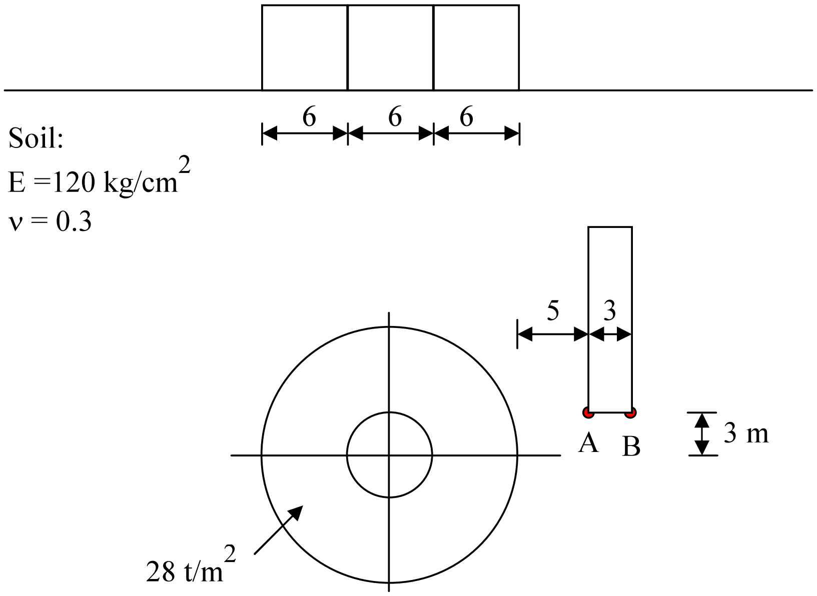
(4) The loads of two buildings are as shown in figure. Assuming that the foundations are flexible and that the loads act on ground surface, find the elastic settlement of points A, B, C and D. Dimensions and soil data are as shown in figure.



(5) For the shown tank, calculate the elastic settlement at the centre and at the edge of the foundation. Assume that the foundation is flexible and that the loads act on ground surface. Dimensions and sail data are as shown in figure



(6) For the shown circular building, calculate the differential elastic settlement between points A and B of the foundation of an adjacent building. Assume that the foundations are flexible and that the load acts on ground surface. Dimensions and soil data are as shown in figure.



* * *